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Enhanced internal quantum efficiency of green emission GaInN/GaN multiple quantum wells by surface plasmon coupling

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1. Introduction

The GaInN-material based light-emitting diodes (LEDs) technology appears to be an excellent candidate in solid-state platform. Improving the LEDs performance within the green gap is challenging, and is also a major focus in the research efforts of GaInN-based LEDs. The c-plane growth of LEDs have a large piezoelectric field in quantum well (QW) due to quantum confined Stark effect (QCSE)[1]. The large piezoelectric field is one of the most critical factors which limit internal quantum efficiency (IQE) in the green gap. In this study, we investigated the enhancement of IQE of green emission QW with coupling the localized surface plasmon (LSP)[2]. Surface plasmon channel is very fast recombination process compared with original path[2]. It is very expected the technique for enhancing IQE. Then, we defined the IQE of GaInN/GaN QWs with LED structure by temperature dependence of photoluminescence (PL).

2. Experiment and results

LED structures were grown by metalorganic vapor phase epitaxy (MOVPE) in a horizontal flow reactor. This LED structure has optimized thin p-GaN layer for coupling LSP to QWs, with expects to enhance the light emission of QWs with coupling LSP. The PL measurement setup could turn the output power density from 1.1 to 756 W/cm^2. PL measurement was carried out with the excitation and collection via the backside of the polished sapphire substrate. The Ag nanoparticles (AgNPs) are fabricated by electron beam evaporation and thermal annealing. Desirable LSP frequencies are able to obtain by adjusting the thickness of the deposited Ag thin-film.

Figure 1 shows the estimation of IQE with various excitation power densities by temperature dependence of PL. We defined the IQE by the PL intensity ratio at room and low temperatures. It indicates that AgNPs are significantly affected the IQE enhancement of the LEDs by LSP coupling. It found that the IQE is improved from 19.4 to 26.2, 26.5, and 44.1 % using AgNPs (4 nm), AgNPs (9.5 nm), and AgNPs (17 nm) at 756 W/cm^2, respectively. The IQE enhancement is attributed to a fast radiative recombination rate through surface plasmon channel.

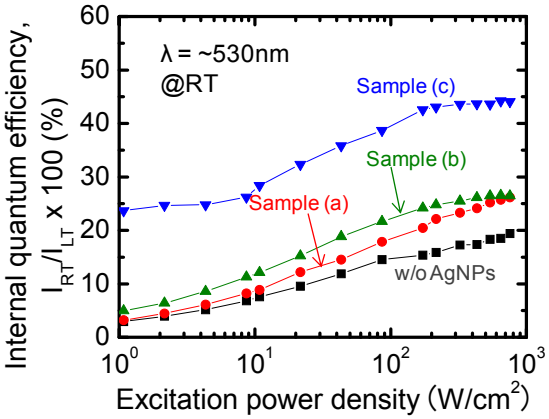

Figure 1. Estimated IQE as function of excitation power density. Ag deposition thicknesses are (a) 4nm, (b) 9.5nm and (c) 17nm, respectively.

3. Conclusions

We investigated that the IQE of GaInN/GaN QWs LEDs with AgNPs is enhanced by QW-LSP coupling. We achieved that the IQE is improved from 19.4 to 44.1% using AgNPs (17 nm) at 756 W/cm^2. This technique expects to boost efficiency in an electrical driven.

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